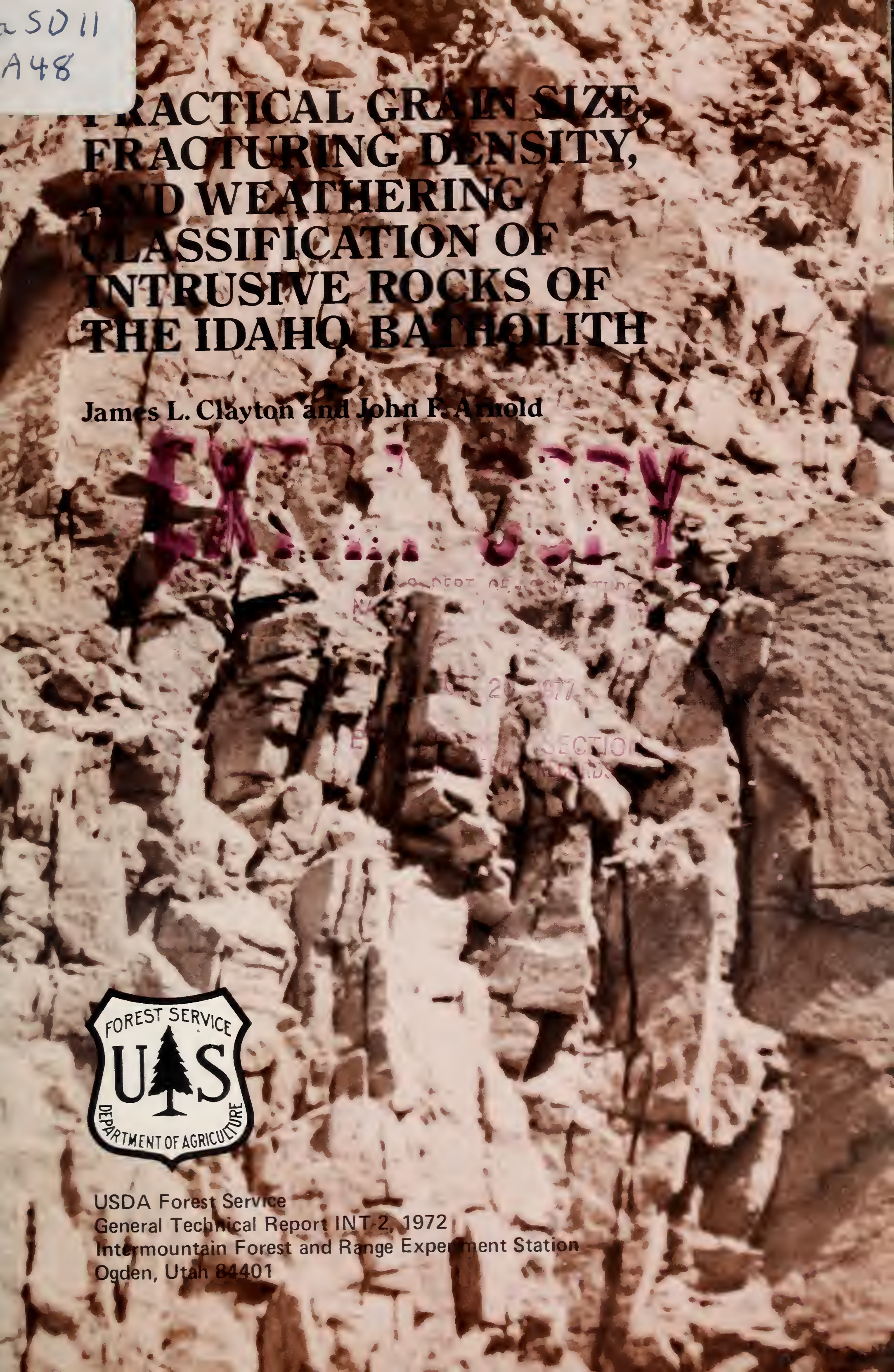
PRACTICAL GRAIN SIZE, FRACTURING DENSITY, AND WEATHERING CLASSIFICATION OF INTRUSIVE ROCKS OF THE IDAHO BATHOLITH

James L. Clayton and John F. Arnold



USDA Forest Service
General Technical Report INT-2, 1972
Intermountain Forest and Range Experiment Station
Ogden, Utah 84401

THE AUTHORS

JAMES L. CLAYTON has served as Associate Research Soil Scientist with the Intermountain Station since 1967. He received his B.S. and M.S. degrees in soil science from the University of California at Berkeley.

JOHN F. ARNOLD received a B.S. degree in forestry from Montana State University and an M.F. degree from the University of Washington. He served as a Forest Soil Scientist with the USDA Forest Service, Pacific Northwest Station, from 1952 to 1954, and from 1954 to 1959 as a Soil Scientist in the Pacific Northwest Region. From 1959 to the present he has served in the Intermountain Region of the Forest Service, first as a Soil Scientist, and from 1968 on as Batholith Liaison Officer.

USDA Forest Service
General Technical Report INT-2
October 1972

PRACTICAL GRAIN SIZE, FRACTURING DENSITY, AND WEATHERING CLASSIFICATION OF INTRUSIVE ROCKS OF THE IDAHO BATHOLITH

James L. Clayton and John F. Arnold

INTERMOUNTAIN FOREST AND RANGE EXPERIMENT STATION
Forest Service
U. S. Department of Agriculture
Ogden, Utah 84401
Robert W. Harris, Director

CONTENTS

ABSTRACT

The degree of weathering, fracturing density, and mineral grain size are important factors to assess in predicting slope stability in the Idaho Batholith. This key provides a practical tool for classifying these factors for granitic rocks of the Idaho Batholith. Some relationships between weathering, fracturing, and slope stability are discussed.

INTRODUCTION

Slope instability and sedimentation problems in the Idaho Batholith have been a subject of increasing concern to forest land managers in the Northern and Intermountain Regions over the last two decades. In light of mounting public awareness, these problems have achieved paramount importance in decisions affecting multiple use of National Forest lands. The relations between rock properties and erosion in the Batholith were recognized as important but largely unknown quantities in land management. Forest Service Research and Administration personnel have been working toward a common goal of defining these relations through Administrative Soil Resource Inventories and soil and rock properties research conducted by the Intermountain Station.

Soil Resource Inventories were started in 1967 as an aid to management planning and are being continued in an effort to stratify land into units presenting similar management problems. Generally, the principal distinctions between units identified by Resource Inventories reflect differences in slope stability and sediment production. During the early phases of mapping by reconnaissance surveys, relations between bedrock structure, texture, weathering and fracturing qualities, and other landscape characteristics, began to materialize. As these relations unfolded, it became apparent that a classification scheme was sorely needed to illuminate the vagaries of bedrock differences.

Through an interchange of ideas, Forest Service Research and Administrative personnel began developing a simple classification scheme that could serve both Administration in reconnaissance mapping and Research in site selection and planning for their study. The Key has evolved through 5 years of use, but an attempt has been made to keep its universality of application in the Batholith, while allowing for more ease of distinction.

The Key has proved to be a useful tool in delineating areas that have a high potential erosion hazard after roadbuilding or logging. Reproducible results have been demonstrated by soil scientists, hydrologists, foresters, and engineers who have used the Key after 1 day of field training.

Later, researchers at the Intermountain Station were formulating plans for an intensive study of soil and rock properties in the Idaho Batholith. This research effort was undertaken jointly by Forest Service Research personnel and soil engineers at Howard University, Washington, D.C. Currently underway, this joint study is a definitive effort at characterizing the mechanical, chemical, mineralogical, and hydrological properties of soil and rock in the Batholith.

THE KEY

The three-part Key is used to classify grain size, density of fracturing (including jointing), and degree of weathering (fig. 1). Generally, its use should be limited to acid igneous rocks composed of crystalline minerals visible to the naked eye. Although their areal extent is small, aplitic and pegmatic dikes, granite porphyries, and microgranite rocks are frequently encountered in the Batholith. The Key is not intended for their classifications, except possibly to describe the fracturing characteristics of these rocks. The Batholith is mainly composed of quartz monzonite (65 percent), granodiorite (23 percent), and tonalite (9 percent), and the Key is useful for all these rock types (percentages are after Larsen and Schmidt[1]).

The Key lists three texture classes:

Class	*Diameter of most crystals*	*Texture*
1	<2 mm.	Fine
2	2 to 5 mm.	Medium
3	>5 mm.	Coarse

The diameter refers to the maximum length visible for inequant quartz and feldspar grains. Grain size of biotites and other accessory minerals should not be used. Texture may be designated either by numbers 1 to 3 or by the terms fine, medium, or coarse.

---

[1]E. S. Larsen, Jr., and R. G. Schmidt. A reconnaissance of the Idaho batholith and comparison with the southern California batholith. U.S. Geol. Surv. Bull. 1070-A, 4 p. 1958.

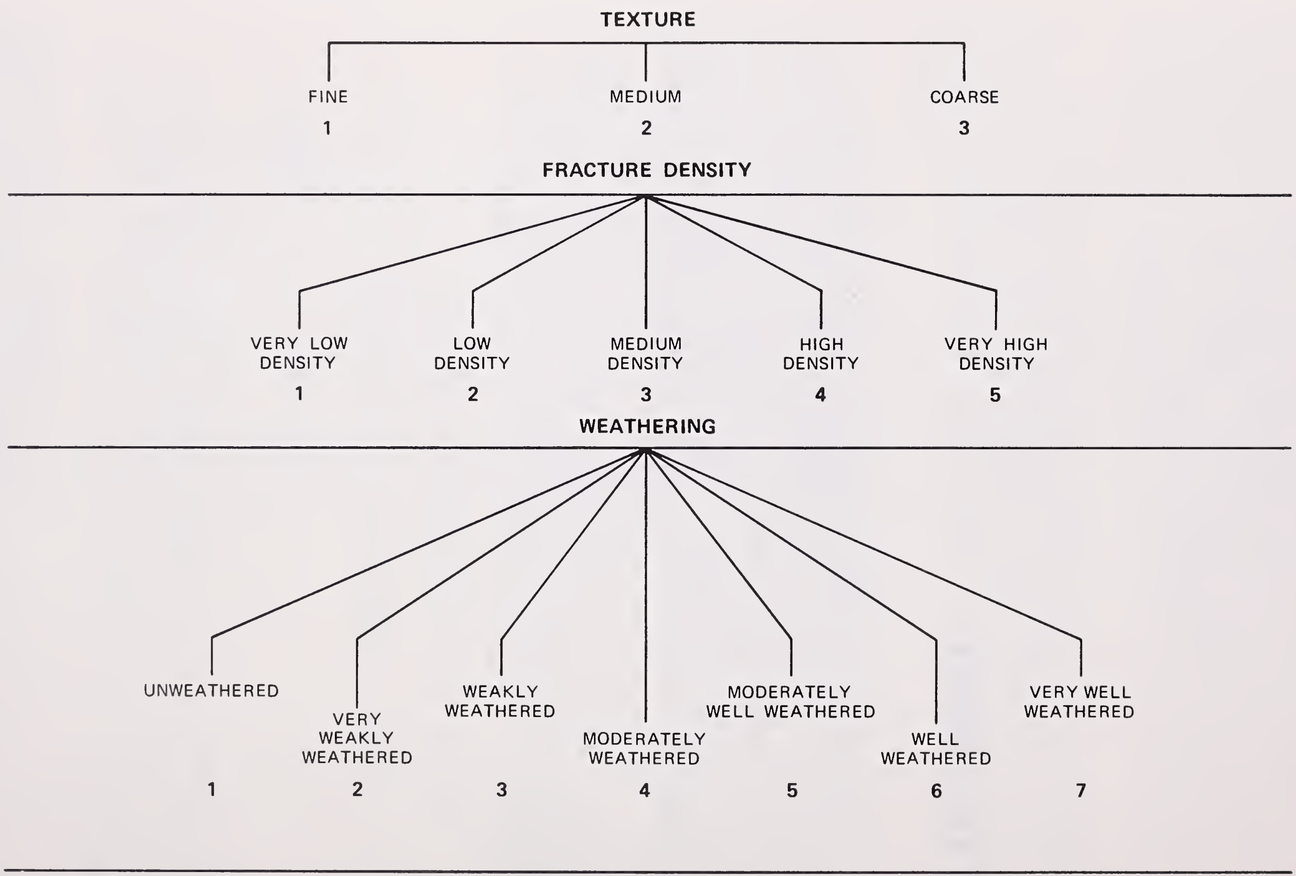


Figure 1.--Three-part Key used to classify grain size, density of fracturing (including jointing), and degree of weathering.

The Key lists five fracture density classes. The criterium for each class is simply the distance between strongly expressed fractures or joints. The authors realize that there are several characteristics of fractures (e.g., direction of strike, amount and direction of dip, and amount of separation between the two sides of fractures) that are not considered. Only the density of fractures was classified for easy use of the Key. If fracture planes are visible in two or more dimensions, a compromise value is usually taken, unless it is apparent that one plane is more important than the other to slope performance.

Class	*Distance between fractures*		*Density*
	(ft.)	*(cm.)*	
1	6	180	Very low
2	4 to 6	120 to 180	Low
3	1.5 to 4	45 to 120	Medium
4	.5 to 1.5	15 to 45	High
5	.5	15	Very high

The rock weathering portion of this Key, the most complex part, includes seven classes of rock weathering. Weathering produces both physical and chemical alterations in granitic rocks, including changes in the following:

1. The amount of iron removed from minerals (e.g., biotite) and deposited as iron oxide stains on mineral grains.

2. The degree of interstitial fracturing (between mineral grains)

3. The degree of fracturing to "hand-size" (∿5-10 cm.) fragments

4. The degree of chemical alteration of biotites and feldspars to secondary minerals.

The weathering index was based on observations of the following:

1. Change in rock color from that of the unweathered condition

2. Mechanical strength of rock (how easily it can be broken manually)

3. Ease of root penetration whether roots penetrate the rock matrix or fractures

4. How distinctly original jointing is preserved

5. The sound a rock hammer makes when striking the rock

6. Whether the rock is spalling (crumbling)

7. Whether the rock is plastic in nature when wet.

CLASSES OF ROCK WEATHERING

Rock was grouped into seven classes of weathering as follows:

Class 1, Unweathered Rock.[2]--Unweathered rock (fig. 2) will ring from a hammer blow; cannot be dug by the point of a rock hammer; joint sets are the only visible fractures; no iron stains emanate from biotites; joint sets are distinct and angular; biotites are black and compact; feldspars appear to be clear and fresh.

Class 2, Very Weakly Weathered Rock.--Very weakly weathered rock (figs. 3,4) is similar to class 1, except for visible iron stains that emanate from biotites; biotites may also appear "expanded" when viewed through a hand lens; feldspars may show some opacity; joint sets are distinct and angular.

Class 3, Weakly Weathered Rock.--Weakly weathered rock gives a dull ring from a hammer blow; can be broken into "hand-sized" rocks with moderate difficulty using a hammer; feldspars are opaque and milky; no root penetration; joint sets are subangular.

Class 4, Moderately Weathered Rock.--Moderately weathered rock (fig. 5) may be weakly spalling. Except for the spall rind, if present, rock cannot be broken by hand; no ring or dull ring from hammer blow; feldspars are opaque and milky; biotites usually have a golden yellow sheen; joint sets indistinct and rounded to subangular.

---

[2]This class is rare in the Idaho Batholith and probably limited to glacially scoured or rejuvenated landscapes.

Class 5, Moderately Well Weathered Rock.--Moderately well weathered rock (figs. 6,7) will break into small fragments or sheets under moderate pressure from bare hands; usually spalling; root penetration limited to fractures, unlike class 6 rock where roots penetrate through the rock matrix; joint sets are weakly visible and rounded; feldspars are powdery; biotites have a light golden sheen.

Class 6, Well Weathered Rock.--Well weathered rock (fig. 8) can be broken by hand into sand-sized particles (grus); usually so weathered that it is difficult to determine if rock is spalling, roots can penetrate between grains; only major joints are preserved and filled with grus; feldspars are powdery; biotites may appear silver or white in thin flakes.

Class 7, Very Well Weathered Rock.--Very well weathered rock has feldspars that have weathered to clay minerals and rock is plastic when wet, no resistance to roots.

Figure 2.--Weathering class 1, fracture density class 2. This rock is unweathered and slightly fractured. Very little sediment is produced from this site.

Figure 3.--Weathering class 2, fracture density class 5. This rock is very well fractured, but only weakly weathered. The road cut is quite stable and will not produce much sediment. Occasional rock fragments may fall to the road below. This rock is highly permeable to water. (Vertical direction of joint planes aids infiltration.) Roots can be found at great depths.

Figure 4.--Weathering class 2, fracture density classes 2 and 3. This rock is weakly weathered and only slightly to moderately fractured. Little sediment is produced. Permeability rates are lower than in figure 3, and a potential exists for overland flow on a saturated soil mantle underlain by this massive rock.

Figure 5.--Weathering class 4 (weakly spalling), fracture density class 2. The subangular to rounded appearance is in distinct contrast to the angular jointing pattern pictured in figure 4, and is a result of weathering by granular disintegration.

Figure 6.--Weathering class 5, fracture density class 3. Contrast the less distinct and more rounded rock edges shown with those of figure 5. Also note the accumulation of sediment below the road cut. Clearly visible is the pegmatite dike that cuts horizontally through the quartz monzonite bedrock.

Figure 7.--Weathering class 5, fracture density class 3. This figure shows the weathering phenomenon known spalling. Note that spall rinds have broken from and lie below the rock. Rinds are easily broken by hand to grus. Roots are confined to joints and fractures in these rocks. Joints are indistinct and rounded.

Figure 8.--Weathering class 6. Note the soft appearance and ease of root penetration. The original structure of the bedrock is obliterated and no fracture class can be assigned. Weathering class 7 rock is similar in appearance, but the plastic nature of that rock class is quite obvious upon hand inspection.

DISCUSSION

Rock weathering and fracturing characteristics are of prime importance in predicting slope stability, particularly after road construction. Generally, as weathering and fracturing classes increase in value, sediment production from these rocks also increases.

Weathering classes 1 and 2 produce essentially no grus-sized sediment. However, if these rocks are highly fractured, coarse rock fragments may cause maintenance problems along roads.

Weathering classes 3, 4, and 5 occur with greatest frequency in the Batholith. They also pose the largest hazard from the volume of sediment production. Rock classes 4 and 5 frequently have spall rinds one-quarter inch or more thick. If all this spalling is eroded away by wind, water, snow, and ice action, it can amount to considerable sediment production. Based on the figure of one-quarter inch of spalling per year, a rectangular road cut, 200 feet in length and averaging 40 feet high, could conceivably produce 5 yards of sediment or 7 tons each year.

Weathering class 7 rock results from intense chemical weathering in place. As a consequence, it is usually found in areas of perennial subsurface ground-water flow, which may be the result of water concentration above a massive impermeable zone of rock. Road cuts through class 7 rock often result in landslide problems in either the cut or the fill slope; consequently, adequate drainage and compaction of fill slopes are required. Utilizing borrowed fill material of some other weathering class would also aid in stabilizing the road. The areal percentage of class 7 rock is small, but frequency of occurrence is high enough to merit close attention in roadbuilding.

The character of bedrock can be predicted with some accuracy from the gross morphological characteristics of the surrounding landscape. In landscapes characteristic of strong fluvial erosion and rapid downcutting by streams (e.g., sharp spur ridges, V-shaped draws), bedrock usually is class 4 or below. Conversely, landscapes with rounded ridges and rather broad drainages characterized by broadly concave cross sections generally indicate that bedrock is more highly weathered. Erosional landforms that have resulted from alpine glaciation are always underlain by hard, unweathered bedrock.

☆ U.S. GOVERNMENT PRINTING OFFICE: 1973 — 784-485 / 21 REGION NO. 8

Headquarters for the Intermountain Forest and Range Experiment Station are in Ogden, Utah. Field Research Work Units are maintained in:

- Boise, Idaho
- Bozeman, Montana (in cooperation with Montana State University)
- Logan, Utah (in cooperation with Utah State University)
- Missoula, Montana (in cooperation with University of Montana)
- Moscow, Idaho (in cooperation with the University of Idaho)
- Provo, Utah (in cooperation with Brigham Young University)
- Reno, Nevada (in cooperation with University of Nevada)